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Effect of Hurricane Eloise on the Benthic Fauna of Panama City Beach, Florida, USA

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Abstract

The effect of Hurricane Eloise in September, 1975 on the benthic fauna inhabiting the swash zone on Panama City Beach, Florida, USA is described. Damage by the storm to the beach and property was considerable. The effect of the storm on the benthic invertebrates was not adverse, as the number of individuals occurring in the swash zone was about the same after the storm as before. The number of species increased after the storm, but later decreased to approximate numbers before the storm. The increase in the number of species was mainly due to the influx of species that normally occur farther offshore of the swash zone. The lack of heavy rainfall that usually accompanies a hurricane was probably a factor enabling benthic organisms that normally live in high salinities to survive.

Introduction

The effect of hurricanes or storms on aquatic animals is often extensive. Observed effects have been mainly due to the deposition of sediments causing suffocation; high turbidities affecting fish and larval forms; oxygen depletion caused by decomposition of exposed organic sediments; erosion of substrates; prolonged low salinities caused by excessive rainfall and runoff; stranded individuals due to wind and tidal action; and the influence of cold water caused by upwelling (Rogick, 1940; Archer, 1947; Engle, 1948; Robins, 1957; Burbanck, 1961; Thomas *et al.*, 1961; Breder, 1962; Tabb and Jones, 1962; Keith and Hulings, 1965; Croker, 1968; Stone and Azarovitz, 1968; Harger and Landenberger, 1971; Andrews, 1973; Munden, 1975).

Information on the effect of hurricanes on benthic animals along the beaches fronting the ocean is limited. Keith and Hulings (1965) made a study in Texas after Hurricane Cindy in 1963, and Croker (1968) in Georgia after Hurricanes Cleo and Dora in 1964. Ansell *et al.* (1972) observed factors affecting the macrofauna on two sandy beaches in India before and during the monsoon season.

Seventeen hurricanes have reached land in the northeastern Gulf of Mexico between 1873 and 1970 (Sugg *et al.*, 1971). The damage from these storms and others that occurred in the Gulf of Mexico amounted to millions of dollars.

The eye of Hurricane Eloise passed over the beach between Fort Walton Beach and Panama City Beach, Florida, on the northeastern coast of the Gulf of Mexico before dawn on September 23, 1975. Wind velocities were approximately 130 mph (209.2 km/h), seas had risen to 10 - 15 feet (3.0 to 4.6 m), with 15-foot (4.6 m) waves pounding the beach. Property damage on Panama City Beach was estimated at 50 million dollars. Extensive erosion took place along the beach, as most of the primary sand dune was removed.

When news that Hurricane Eloise would pass through the Panama City Beach area was received, preparations were made to measure the effects of the storm on the benthic invertebrates inhabiting the swash zone. The swash zone in this study is defined as the beach face, or the sloping surface of the beach that is covered by the run-up of water brought by waves (Russell, 1969). Since 11 consecutive months of sampling had been conducted in the swash zone before the storm, data on the fauna inhabiting the swash zone were available. This was an excellent opportunity to study the population of benthic invertebrates before and after the passing of a hurricane.

Special benthic sampling was initiated in the swash zone at Panama City

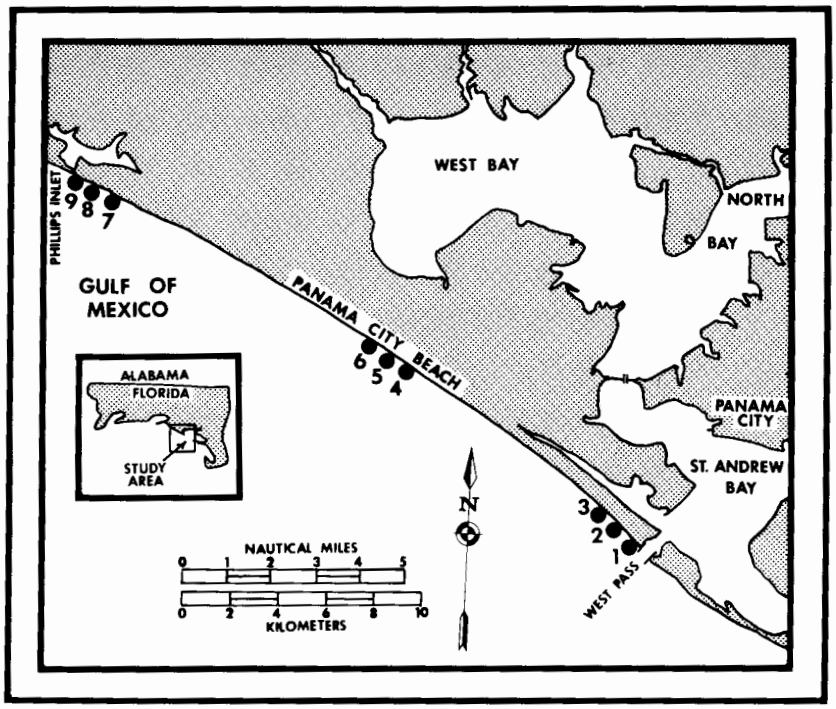

Fig. 1. Station locations in the Gulf of Mexico between West Pass and Phillips Inlet

Table 1. Water temperature and salinity in swash zone at Panama City Beach, Florida, before and after Hurricane Eloise, which passed over beach before dawn on September 23, 1975

Date (1975)	Water temperature (°C)		Salinity (‰)	
	Average	Range	Average	Range
22 Sept.	26.5	26.0-27.2	30.36	29.83-30.94
24 Sept.	25.4	24.8-25.8	30.54	28.56-31.89
25 Sept.	24.7	22.9-27.5	31.97	30.83-33.06
26 Sept.	20.5	19.9-21.9	31.23	29.44-32.00
29 Sept.	25.6	24.5-26.5	33.70	32.06-34.33
2 Oct.	24.2	23.5-24.6	31.73	30.83-33.11
7 Oct.	24.1	23.5-24.9	30.73	29.33-31.56
21 Oct.	22.1	20.1-23.9	31.49	29.78-32.83
Average	24.2	19.9-27.5	31.47	28.56-34.33

Table 2. Abundance of benthic fauna at 9 sites in swash zone of Panama City Beach, Florida, before and after Hurricane Eloise

Sampling date (1975)	No. of days after storm	Total no. of individuals	Total no. of species	Average no. of individuals/m^2
22 Sept.	-	491	9	873
23 Sept.	0			
24 Sept.	1	465	17	827
25 Sept.	2	677	16	1,204
26 Sept.	3	914	21	1,627
29 Sept.	6	1,358	15	2,415
2 Oct.	9	817	5	1,453
7 Oct.	14	465	6	827
21 Oct.	28	429	13	763
Sept. 22-Oct. 21		5,616	43	
Average		702	12.8	1,249

Beach one day prior (September 22, 1975) to the storm. Sampling continued daily for 3 days after the storm and thereafter at increasingly longer intervals until 28 days after the storm.

The purpose of this report is to present our findings on the number of species, number of individuals, and number of individuals per unit area in the swash zone on Panama City Beach, before and after the passing of Hurricane Eloise.

Materials and Methods

The benthic fauna was sampled with a stainless-steel plug sampler. The sampler covers 1/64 m^2 and penetrates to a depth of 23 cm.

Samples were collected at 9 stations along the beach between West Pass and Phillips Inlet (Fig. 1). At each station, 8 plug samples were taken. Each sample was placed in a stainless-steel 24 mesh sieve with an opening of 0.701 mm^2 and sieved. The remnant portion in the sieve was stained with Rose Bengal and preserved in 10% formalin-seawater solution.

At the laboratory, the samples were rinsed in fresh water. The organisms were sorted into major animal taxa, placed in isopropyl alcohol, and subsequently identified to the lowest practi-

cable taxonomic level and then enumerated.

A surface water sample was collected during each station visit. The water temperature was taken with a mercury thermometer, and the salinity was determined with a Goldberg refractometer.

Sediments

Surface sediments were collected monthly for 11 months prior to the hurricane at the same 9 sites (Saloman, 1976).

The sediment in the swash zone was, on the average, over 99.6% sand. The remaining 0.4% was about equally divided between the pebble and granule fraction and the silt fraction. The average percentage of the total sample weight of carbonate, total carbon, and organic carbon was 0.085, 0.134, and 0.050%, respectively. Statistical formulas by Folk and Ward (1957) were used for the calculations of sediment parameters. The average mean grain size of these surface sediments was 0.332 mm, the average standard deviation was 0.620 phi, average skewness 0.019, and average kurtosis 1.101.

Hydrology

The water temperature and salinity in the sampling area did not change substantially after the hurricane. The total rainfall associated with the storm was 0.66 inches (1.7 cm). Water temperature did decrease, which is normal during this time of year, and salinity increased slightly (Table 1). Thus, the influence of these two factors on the abundance and diversity of the benthic macroinvertebrates was believed to be negligible.

Macrofauna

Samples of benthic macrofauna were collected on 8 days, 1 day prior to the storm and on 7 different dates afterwards. The dates were September 22, 24, 25, 26, 29, October 2, 7, and 21, 1975.

Individuals

The number of individuals increased from 465 at the 9 stations on the first day after the storm to 1,358 individuals 6 days after the storm. Nine days after the storm, the number of individuals had decreased and continued dropping to the pre-storm level through the last sampling date (Table 2).

The total number of individuals at each station in the 8 sampling trips was higher at the stations on the west end of the study area. At Stations 1-3, the total number of individuals was 1,342; at Stations 4-6, it was 1,902; at Stations 7-9, the number was 2,372 (Table 3). Storm damage was greatest at the western end of the study area.

The increase in individuals after the storm was mainly caused by an increase in numbers of *Emerita talpoida* (Fig. 2). Although the total number of species increased, it was still very low. Population levels fluctuate to a great degree in this habitat (Table 4).

Species

The number of species at the 9 sites nearly doubled on the day following the storm and remained high for 6 days after the storm (Table 2). On the 9th and 14th days after the storm, the number of species decreased to 5 and 6, respectively. There was an increase in number of species to 13, 28 days after the storm. This total was still lower than the number of species that was caught on each of the 4 sampling days after the storm.

The large increase in the number of species after the storm was surprising, as we thought originally that the populations of benthic macroinvertebrates would be either killed by the force of the waves, suspended in the water column and then washed away by the currents, smothered by the deposition of sand, or left stranded on the beach above the receding water line. In 11 months of sampling prior to the storm at the same 9 sites, the average number of species caught per month for the 11-month period was only 7.1. The highest number of species collected during a single month from the 9 sites was 12 (Table 4).

A total of 43 species was caught at the 9 sites on the 8 sampling trips. Three species, *Emerita talpoida, Haustorius* n. sp., and *Scolelepis squamata* comprised 92.8% of the individuals, while 18 species were represented by a single individual (Table 3).

Some species were not found in the swash zone prior to Hurricane Eloise. In 12 months of sampling (November 1974 through October 1975), 25 species of macroinvertebrates were present at the same 9 sites (Saloman, 1976). Following the storm, 7 previously unrecorded species occurred in the samples. These included 4 species of amphipods (*Maera* sp. 1, *Maera* sp. 2, *Microprotus* sp., and *Netamelita* sp.), and one caridean shrimp (*Peri-*

Table 3. Number of individuals of each species of benthic macroinvertebrates collected at 9 sites in swash zone of Gulf of Mexico on Panama City Beach before and after Hurricane Eloise

Species	Stations									Total
	1	2	3	4	5	6	7	8	9	
Nemertinea										
Unidentified sp. 1	5	6	11	6	4	4	1	2	2	41
Unidentified sp. 2	0	0	0	0	0	0	0	0	1	1
Nematoda										
Unidentified sp.	0	0	0	0	0	0	0	0	2	2
Polychaeta										
Ceratonereis irritabilis	0	0	0	0	0	1	0	0	0	1
Dispio uncinata	3	1	0	2	1	2	7	4	0	20
Glycera oxycephala	1	0	0	0	0	0	0	0	0	1
Lumbrineris paravapedata	0	0	0	0	0	0	0	1	0	1
Onuphis eremita oculata	0	0	0	1	0	0	0	0	0	1
Paraonis fulgens	34	3	1	2	3	2	0	0	0	45
Scolelepis squamata	62	114	41	77	32	113	127	66	118	750
Pelecypoda										
Cuna dalli	0	1	0	0	0	0	0	0	0	1
Donax texasianus	19	31	7	9	12	5	19	10	29	141
Pycnogonida										
Unidentified sp.	0	0	0	0	1	0	0	0	0	1
Cumacea										
Mancocuma sp.	1	0	0	0	4	0	0	0	9	14
Unidentified sp.	2	0	1	1	0	0	0	0	0	4
Tanaidacea										
Hargeria rapax	0	0	0	0	2	0	0	0	0	2
Kalliapseudes sp.	0	0	0	0	1	0	0	0	0	1
Isopoda										
Ancinus depressus	2	5	0	2	0	0	0	0	9	18
Scyphacella arenicola	0	0	0	0	0	0	0	0	3	3
Unidentified sp.	0	0	0	0	0	0	0	0	1	1
Amphipoda										
Acanthohaustorius n. sp.	1	0	2	0	0	0	0	0	0	3
Ericthonius n. sp.	1	0	0	2	0	0	1	1	0	5
Haustorius n. sp.	70	110	216	108	253	209	160	136	59	1,321
Listriella sp.	0	0	0	0	1	1	0	0	0	2
Maera sp. 1	0	0	0	0	1	1	2	0	0	4
Maera sp. 2	0	0	0	0	1	0	2	0	0	3
Microprotopus sp.	0	0	0	1	1	0	0	0	0	2
Netamelita sp.	0	0	0	0	1	0	1	0	0	2
Nototropis sp.	0	0	0	0	0	0	0	2	0	2
Protohaustorius n. sp.	0	0	0	0	0	0	0	1	0	1
Talorchestia n. sp.	0	0	1	0	0	0	0	0	0	1
Tiron sp.	0	0	0	1	0	0	0	0	0	1
Unidentified sp.	0	0	0	1	0	0	0	0	0	1
Caridea										
Periclimenes longicaudatus	0	0	0	0	0	0	0	0	1	1
Anomura										
Emerita benedicti	3	0	0	0	0	0	0	0	0	3
Emerita talpoida	156	315	101	415	330	264	499	280	779	3,139
Lepidopa benedicti	3	4	5	8	9	6	8	5	6	54
Pagurus impressus	0	0	0	0	0	0	1	0	0	1
Brachyura										
Pinnixa cristata	0	0	1	0	0	0	11	3	0	15
Pinnixa sayana	0	0	0	0	0	0	3	0	0	3
Asteroidea										
Astropecten articulatus	0	0	1	0	0	0	0	0	0	1
Ophiuroidea										
Ophiophragnus filograneus	0	0	1	0	0	0	0	0	0	1
Cephalochordata										
Branchiostoma floridae	0	0	0	1	0	0	0	0	0	1
Total	363	590	389	637	657	608	842	511	1,019	5,616

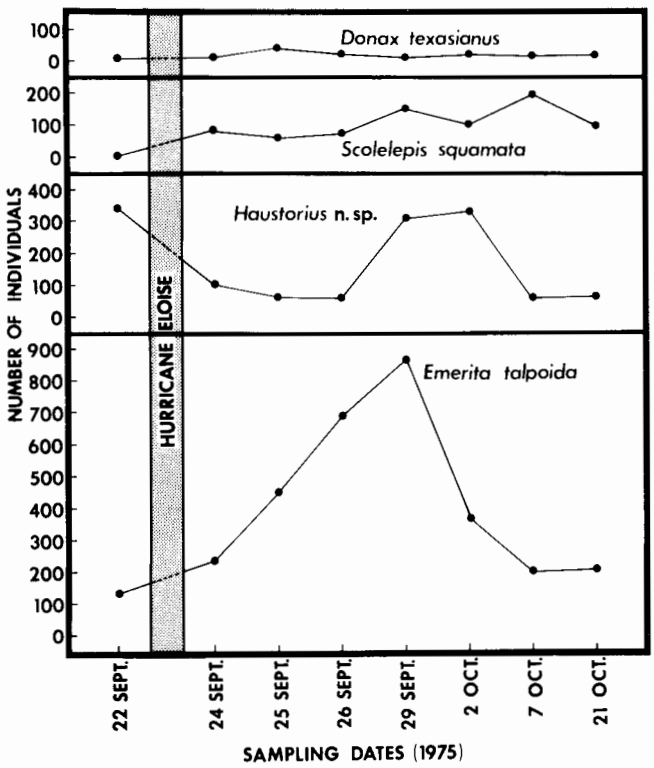

Fig. 2. Abundance of 4 most abundant macroinvertebrates on 8 sampling dates in swash zone of Panama City Beach before and after Hurricane Eloise

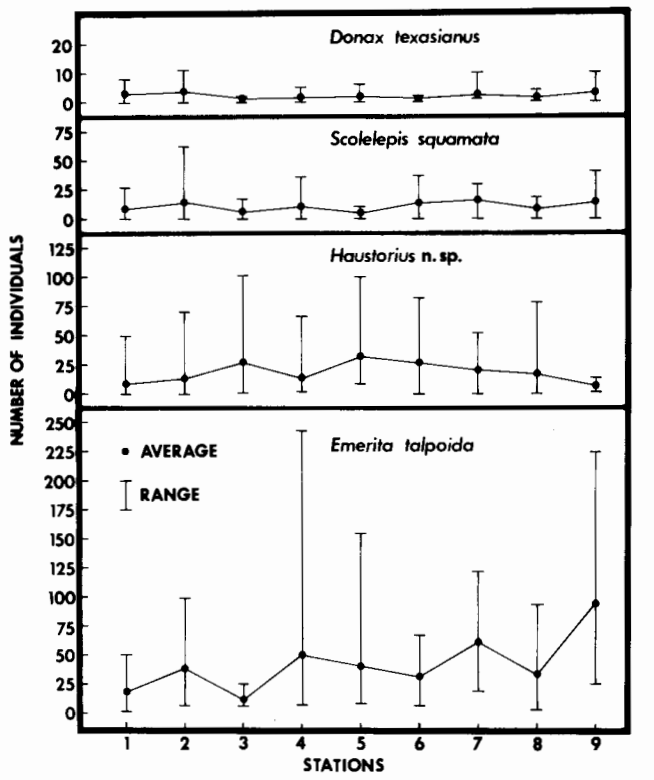

Fig. 3. Abundance of 4 most abundant macroinvertebrates at 9 transect stations in swash zone of Panama City Beach before and after Hurricane Eloise

Table 4. Abundance of benthic macroinvertebrates at 9 sites in swash zone of Panama City Beach, Florida, for 11 months prior to Hurricane Eloise

Date	No. of species	No. of individuals
1974		
Nov.	4	86
Dec.	7	425
1975		
Jan.	4	967
Feb.	8	1,169
March	6	439
April	6	642
May	9	7,384
June	5	4,947
July	11	736
Aug.	12	486
Sept.	6	424
Nov. 1974-Sept. 1975	26	17,705

climenes longicaudatus). None of these newly occurring species was abundant; the total number of individuals collected of the 7 species was 15 (Table 3).

The three most abundant species were the anomuran *Emerita talpoida*, the amphipod *Haustorius* n. sp., and the polychaete *Scolelepis squamata*. *Donax texasianus*, the common pelecypod, ranked fourth in abundance.

Emerita talpoida was present at each station on all sampling trips. The number of individuals at the stations along the beach varied from a low of 101 at Station 3 to a high of 779 at Station 9 (Table 3). The widest range of individuals (7 to 242 individuals) during the 8 sampling days occurred at Station 4 (Fig. 3). The abundance of this species mainly accounted for the increase in individuals occurring after the storm. The specimens of *E. talpoida* occurring after the storm were quite small (averaging approximately 2 mm in length), which indicated recruitment and recolonization of young individuals to the beach after the storm. The new recruitment to this population increased the number of individuals for the 6 days after the storm (Table 2 and Fig. 2). We are unable to explain the rapid decrease in numbers of *E. talpoida* after September 29.

A new species of amphipod, *Haustorius* n. sp. (E.L. Bousfield, personal communication) was one of the dominant animals inhabiting the swash zone. It was present in 86% of the samples during the 8 sampling days. Its abundance was highest before the storm (Fig. 2). For a few days after Eloise, its numbers decreased. From the 29th of September to the 2nd of October they increased to about pre-Eloise numbers (Fig. 2). After October 2, the numbers of *Haustorius* n. sp. decreased to levels of those of the first 3 days following the storm.

The numbers of *Haustorius* n. sp. were higher at the central stations of the sampling area than at the two ends. The average number of *Haustorius* n. sp. caught in the 8 sampling visits was 16.6 on Stations 1-3 (east end); 23.7 on Stations 4-6 (center); and 14.8 on Stations 7-9 (west end) (Fig. 3).

The polychaete *Scolelepis squamata* was present in 86% of the samples during the 8 sampling days. Its abundance increased from a low of 3 individuals on the day before the storm to a high of 192 individuals 14 days after the storm (Fig. 2). The abundance of *S. squamata* and *Donax texasianus* along the beach was low and fairly uniform during the study period (Fig. 3).

Discussion

The effect, if any, of Hurricane Eloise on the numbers of benthic macroinvertebrates inhabiting the swash zone was difficult to determine. Hurricane Eloise caused considerable damage to the beach property and eroded the primary sand dune. Numbers of individuals of the four dominant species for various numbers of days after the storm were approximately the same or higher than before the storm. Individuals of the most abundant species that inhabit this swash zone normally fluctuate considerably. The variation in the number of individuals between some months prior to Eloise was considerably more than the increase in individuals after Eloise. The increase of individuals after Eloise was mainly due to the numbers of *Emerita talpoida*. This increase in the numbers of *E. talpoida* was probably not due to the effect of the storm, as the recruitment of the young and the arrival of Eloise was probably a coincidence.

Previously obtained data show that from August through October, 1974, the average size of *Emerita talpoida* in the swash zone was about 2 mm (data on file at the Panama City Laboratory, Panama City, Florida). During the 11 months prior to the storm, Saloman (1976) recorded the highest number of individuals in early September at the same 9 sites visited in this study. The length of those *E. talpoida* collected in early September was also about 2 mm.

The presence of small individuals over a long period may be due to several factors. Efford (1967) noted that *Emerita talpoida* grows only in the second summer. The larval development time is 30 days (Rees, 1959), however, differences in development time due to varying water temperatures and exposure to light have been described for other species of *Emerita* (Hanson, 1969; Efford, 1970). Spawning throughout the year by *E. talpoida* is possible, as year-round spawning by *E. portoriciensis* has been observed (Goodbody, 1965). In addition, there are differences in growth and longevity between sexes (Efford, 1967), that could account for the presence of small individuals in the swash zone in almost all months.

The most abundant species found in the swash zone following the storm were the same as those that normally occur in this zone. These species that normally inhabit the swash zone are adapted to this high energy habitat by having a relatively quick burrowing ability. The species not found previously in the swash zone were those that normally occur offshore. Hurricane Eloise apparently brought them inshore.

Heavy rainfall that usually accompanies a hurricane and fresh water runoff causing prolonged low salinities were lacking. Only 0.66 inches (1.78 cm) of rain was recorded. This was probably the main factor that enabled the macroinvertebrates that normally inhabit high salinity areas to survive the effects of the hurricane. Croker (1968) found little change in the distribution and abundance of haustoriid amphipods inhabiting the beach of Sapelo Island, Georgia, following two hurricanes in 1964. The mortality that occurred to the amphipods was attributed to large volumes of fresh water. Keith and Hulings (1965) also noted that haustoriid amphipod abundance in subtidal sand in Texas was relatively unaffected by Hurricane Cindy in 1963, but organisms living in a mud substrate were almost eliminated.

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